

## SORPTION CONCENTRATOR WITH ELECTRICALLY HEATED DESORPTION REGENERATION

### FIELD OF THE INVENTION

5 This invention relates to sorption concentrators, such as a rotary sorption concentrator, for removing contaminants from a gas stream, including volatile organic compounds, wherein the sorption units include a semi-conductive foil substrate, preferably an aluminum foil substrate, having convoluted surfaces and parallel channels extending generally parallel to the direction of the gas flow coated with a sorption 10 material and a source of electric current connected to the foil substrate resistively heating the substrate during the desorb or regeneration cycle.

### BACKGROUND OF THE INVENTION

Sorption concentrators are devices that use sorption principles to capture contaminants in a dirty gas stream, particularly including volatile organic compounds. 15 The sorption process generally utilizes either adsorption materials or absorption materials. Adsorption is the process by which contaminants are removed from a gas stream through adherence of the contaminants to the surface of the adsorption material. Absorption is the process of absorbing the contaminants into the inner structure of the absorbent. Although there are many types of sorption concentrators on the market, they 20 can be categorized into two categories, namely (i) fixed bed type, and (ii) moving bed type including rotary concentrators as disclosed, for example, in prior U.S. Patent No. 5,693,123 assigned to the assignee of this application.

As will be understood by those skilled in this art, the efficiency of sorption devices is a function of the type and quantity of the sorption material used. The 25 sorption material may include, for example, activated carbon, zeolite or porous polymers for removal of volatile organic compounds from a gas stream. Once in use, the sorption material gradually attains saturation, a condition wherein the sorption material reaches the maximum holding capacity of the contaminant. Once saturation is reached, the sorption concentrator ceases to function unless the sorption material is 30 either replaced or regenerated. In most cases, in situ regeneration of sorption material is far more economical than replacement. Conventionally, regeneration is achieved by supplying heat to the sorption material by means of directing a stream of heated clean gas, generally heated air, over the sorption material. This method then includes (i)

heating the fluid, generally clean air, (ii) collecting and directing a stream of hot fluid to the sorption material, (iii) contact between the hot fluid and the sorption material, and (iv) sweeping away the spent fluid along with the released contaminants, generally back to the inlet of the concentrator. The steps involved in this method make it  
5 complicated and costly to manufacture and operate.

The prior art also includes various means of heating the sorption units of a concentrator, including rotary concentrators. For example, the above-referenced U.S. Patent No. 5,693,123 discloses a rotary concentrator wherein the sorption units are formed by extruding a slurry containing a sorption material and a binder into blocks  
10 having parallel passages and, in one embodiment, an electrically conductive material is added to the slurry, such as carbon or metal shavings. However, the desorption process includes directing a hot desorb gas through the blocks to remove impurities from the passages. U.S. Patent No. 5,505,825 discloses an electrically conductive sorption system including an electrically conductive sorbent bed having a multiplicity of  
15 adsorption sites. U.S. Patent No. 5,972,077 discloses a system for separating gases which includes an adsorption member formed of a carbon fiber composite molecular sieve for adsorption of carbon dioxide and hydrogen sulfide, wherein a voltage is applied to the adsorbent member causing the adsorbed molecules of the gas to be desorb. Finally, U.S. Patent No. 5,501,007 discloses a method of producing sorbing  
20 sheets and laminates for removing gaseous bodies such as water vapor, organic solvent vapor and odor constituents having a honeycomb construction formed of convoluted thin sheets of ceramic fiber with electrically resistive wires adhered to the sheets. An electrical current is impressed across the resistive wires to heat the sorbing sheets during the desorb cycle. The prior art also includes automotive catalytic converters  
25 with honeycomb or corrugated metal strips, although catalytic converters are not considered related art to sorption concentrators.

The prior art still fails to disclose a simple and inexpensive construction for sorption concentrators wherein the sorption units may be rapidly heated during the desorb cycle to regenerate the sorption material without the requirement of directing a  
30 stream of hot fluid over the sorption material.

### SUMMARY OF THE INVENTION

As set forth above, the sorption concentrator of this invention is adapted to remove contaminants entrained in a gas stream, particularly but not exclusively including volatile organic compounds. The sorption concentrator thus includes a plurality of adjacent sorption units which are generally rectangular in construction, a gas flow system directing gas to be cleaned through a majority of the sorption units during a sorption cycle and directing a separate clean gas stream through the remaining sorption units during a desorb or regeneration cycle. Where the sorption concentrator of this invention is a rotary concentrator of the type disclosed in the above-referenced U.S. Patent No. 5,693,123, the rotary concentrator includes a rotating frame for mounting the sorption units having a predetermined rotational cycle and the gas flow system directs dirty gas to be cleaned to a majority of the rotational cycle of the frame during the sorption cycle and directing a separate clean gas stream over a smaller percentage of the rotational cycle of the frame during the desorb or regeneration cycle.

The sorption units of the sorption concentrator of this invention each include a semi-conductive foil substrate, most preferably an aluminum foil substrate, having convoluted surfaces and parallel passages extending generally parallel to a direction of the flow of gas during the sorption and desorb cycles coated with a sorption material, and a source of electrical current connected to the semi-conductive foil substrate resistively heating the sorption units during the desorb cycle. Although various materials may be selected for the semi-conductive foil substrate, aluminum foil has the advantages that it may be easily and economically formed into the desired shape and rapidly heats during the desorb or regeneration cycle, eliminating the requirement for directing a hot gas stream over or through the sorption material during the desorb cycle.

In the preferred embodiment, the aluminum foil substrate has a thickness of between 0.005 mm and 2 mm, more preferably between 0.05 to 1 mm and most preferably between 0.1 mm and 0.3 mm. In the most preferred embodiment, the semi-conductive foil substrate is formed into a honeycomb construction which can take several forms. The preferred embodiments include a plurality of parallel curvilinear or corrugated semi-conductive foil sheets each affixed to a planar sheet and bonded together to form a unitary honeycomb structure having a plurality of small parallel

passages. In one embodiment, the corrugations are triangular and in another disclosed embodiment, the corrugations are curvilinear. Alternatively, the semi-conductive foil substrate may be formed of thin parallel tubes which are bonded together to form the substrate. The tubes may be circular or any suitable configuration including polygonal 5 tubes providing planar surfaces for bonding the tubes together to form the sorption units.

The selection of the sorption material will depend upon the application for the sorption concentrator as is known in this art. In the preferred embodiment of the sorption concentrator for removing volatile organic compounds from a gas stream, the 10 sorption material is selected from the group consisting of activated carbon, zeolite and porous polymers. The semi-conductive foil substrate may be coated with the sorption material by conventional means, including forming a slurry of the sorption material and a suitable binder, dipping the semi-conductive honeycomb foil substrate into the slurry and allowing the slurry to dry and generally includes heating the slurry to remove the 15 solvent and dry the sorption material on the semi-conductive foil substrate.

As will be understood from the summary of this invention, the electrically heatable sorption units of this invention may be easily and inexpensively fabricated at a relatively low cost and the sorption units will heat rapidly during the desorb or regeneration cycle, wherein the clean gas sweeps away the contaminants sorbed during 20 the sorption cycle without requiring directing a stream of hot fluid over the sorption material. Other advantages and meritorious features of the sorption concentrator of this invention will be more fully understood from the following description of the preferred embodiments, the appended claims and the drawings, a brief description of which follows.

#### 25 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a top view of one embodiment of a rotary concentrator of this invention;

Figure 2 is a partial side elevational view of Figure 1;

Figure 3 is a partial side view of Figure 1 in the direction of view arrows 3-3;

30 Figure 4 is an enlarged view of Figure 3;

Figure 5 is a side view similar to Figure 3 of an alternative embodiment of a sorption unit of a concentrator of this invention;

Figure 6 is a side view of an alternative embodiment of a sorption unit of a concentrator of this invention; and

Figure 7 is a side view similar to Figure 3 of a further alternative embodiment of a sorption unit of a concentrator of this invention.

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### DESCRIPTION OF THE PREFERRED EMBODIMENTS

As set forth above, the sorption concentrator of this invention may be either stationary or rotary. Figure 1 shows a preferred embodiment of a rotary concentrator 20 incorporating the improved electrically conductive sorption units 22 of this invention. As will be understood by those skilled in this art, the sorption units 22 are supported on a rotary frame element (not shown), such that the sorption units 22 are rotated or indexed about the central axis as shown, for example, by arrow 24. The rotary concentrator 20 is generally enclosed within a housing or plenum (not shown) which receives the fluid, generally gas, to be cleaned and the dirty gas then flows through the sorption units 22 generally from the outside to the inside as shown by arrows 26, but the flow can also be reversed. The clean gas may then be vented to atmosphere. As the rotary concentrator 20 is indexed, one of the sorption units is received in a desorb or regeneration plenum 28, wherein clean gas such as air is introduced under pressure through inlet 30 and the contaminants removed from the sorption unit is discharged through outlet 32. The outlet 32 is generally connected to the inlet of the rotary concentrator to remove contaminants discharged from the sorption unit during regeneration. As thus far described, the rotary concentrator may be conventional as disclosed in the above-referenced U.S. Patent No. 5,693,123.

Figures 2 to 4 illustrate one preferred embodiment of an electrically conductive sorption unit 22 of this invention. The electrically conductive sorption units each include a generally rectangular housing 34, as shown in Figure 2, having open ends 36, which receive the gas, and an electrically conductive honeycomb sorption unit 38 is received in each of the housings 34. In the embodiment of the sorption units 38 shown in more detail in Figures 2 to 4, the honeycomb construction includes a plurality of parallel corrugated sheets, preferably formed of aluminum film 40, separated by planar sheets of aluminum film 42, forming a semi-conductive honeycomb substrate or matrix having parallel channels 44. As shown in Figure 4, the substrate is coated with a

sorption material 46 such that contaminants in the dirty gas directed through the channels 44 are sorbed by the sorption material 46 either by adsorption or absorption.

As shown in Figure 1, all but one of the sorption units 22 are receiving "dirty gas" or gas containing contaminants, such as volatile organic compounds, during 5 normal operation of the rotary concentrator 20. As the rotary concentrator rotates or indexes as shown by arrow 24, one of the sorption units is received in the regeneration or desorb plenum 28, wherein clean gas is received through inlet 30 and directed through the parallel channels 44 shown in Figures 3 and 4 to remove the contaminants from the sorption material 46 regenerating the sorption unit. In a conventional rotary 10 concentrator of the type shown in Figure 1, heated gas is directed through the sorption unit for regeneration. However, with the electrically conductive sorption units 22 of this invention, the requirement for heated gas for regeneration is eliminated. Instead, an electric current is connected to the semi-conductive substrate of the honeycomb sorption unit 38 in the desorb plenum 28, as shown schematically at 48 in Figure 1, 15 which rapidly heats the substrate including the corrugated sheets 40 and planar sheets 42, thereby heating the sorption material 46 shown in Figure 4. The clean gas then sweeps away the contaminants, regenerating the sorption unit without requiring heating of the desorb gas.

In the preferred embodiment of the sorption concentrator of this invention, the 20 substrate is formed of relatively thin sheets of aluminum or aluminum foil to promote rapid heating of the substrate. As will be understood, however, other semi-conductive substrates may be utilized. Aluminum foil is preferred because it heats rapidly with a minimal electric current and is easily fabricated into a honeycomb configuration by known techniques. The corrugated and planar sheets 40 and 42, respectively, are 25 preferably bonded together to form a unitary honeycomb substrate, wherein the corrugated and planar sheets are in electrical contact as shown in Figure 4. The bonding of the sheets may be accomplished by any suitable means including brazing, welding or use of an electrically conductive adhesive. When the honeycomb substrate is formed, the sorption material 46 may be bonded to the substrate by forming a slurry 30 of particulate sorption material, preferably selected from the group consisting of activated carbon, zeolite or porous polymers for removal of volatile organic compounds, a suitable bonding agent and generally including a solvent. The substrate

is then dipped into the slurry, removed and permitted to dry, wherein the substrate may be heated to remove the solvent. This method of coating a substrate is known in the art and therefore no further description is required. The preferred electrical resistivity of the substrate will depend upon the material selected for the substrate and the thickness 5 of the substrate. In the preferred embodiment, wherein the substrate is formed from aluminum foil, the aluminum foil substrate has a thickness of between 0.005 mm and 2 mm, more preferably between 0.05 mm and 1 mm and most preferably between 0.1 mm and 0.3 mm, such that the substrate may be easily fabricated and rapidly heats during the desorb cycle or regeneration as described.

10 Figures 5 to 7 illustrate alternative embodiments of the honeycomb construction for the sorption units 22 shown in Figure 1. In Figure 5, the honeycomb construction is formed by a plurality of nested hexagonal tubes 48. The advantage of this configuration is that the planar side faces of the nested hexagonal tubes 48 provide surface to surface contact for bonding, providing a more rigid structure which may be 15 easily fabricated by conventional methods. As will be understood, various polygonal tubes may be utilized. Figure 6 illustrates an alternative embodiment of the honey construction shown in Figure 3, wherein the corrugated sheets 50 are curvilinear or sinusoidal, rather than triangular as shown in Figure 3, providing a greater surface area for bonding to the parallel sheets 52. Finally, the honeycomb structure shown in Figure 20 7 is formed by a plurality of circular tubes 54 which are bonded together as described above. Alternatively, the circular tubes 54 may be nested. After forming the honeycomb construction shown in Figures 5 to 7, the honeycomb is coated with a sorption material as described above and shown at 46 in Figure 4. The honeycomb construction is preferably formed into a generally rectangular block and received in a 25 housing, such as shown at 34 in Figure 2, and used in a concentrator such as the rotary concentrator 20 shown in Figure 1. That is, the fluid or gas to be cleaned flows through the channels of the honeycomb construction as shown by arrows 26 and the substrate is heated by an electrical current 48 in the regeneration chamber or desorb plenum 28 as described above.

30 As will be understood by those skilled in this art, various modifications may be made to the concentrator of this invention within the purview of the appended claims. For example, the electrically conductive sorption units 22 may be utilized in a

stationary concentrator, wherein one of a plurality of sorption units is heated by electric current during the regeneration cycle of the sorption units. Various other configurations of honeycomb construction may also be utilized. In the preferred embodiments, the channels to the honeycomb construction are generally parallel to

5 provide laminar flow through the electrically conductive sorption units. Further, other materials may be utilized for the substrate, provided that resistive heating of the substrate occurs when an electrical current is applied to the substrate as described. Having described the preferred embodiments of the sorption concentrator of this invention, it is now claimed, as follows: